Yale Carbon Containment Lab

August 23, 2022

VIA EMAIL: Burgess.Karen@epa.gov

Karen Burgess
U.S. EPA Region 10
Water Division
Groundwater and Drinking Water Section
1200 Sixth Avenue, Suite 155
Seattle, WA 98101

RE: Preliminary Geological Sequestration Well Classification; Response to Request for Additional Information

Dear Ms. Burgess:

Yale University's Carbon Containment Lab (Yale CCL) appreciates this opportunity to provide your office and the Washington State Department of Ecology with additional information supporting Yale CCL's request for confirmation that it may properly pursue a Class V Underground Injection Control (UIC) permit to study the geological sequestration of carbon dioxide (CO_2) in the Columbia River Basalt Group (CRBG). Thank you for your patience while my team and I prepared our responses.

Yale CCL is committed to developing solutions to redress the climate crisis. Yale CCL plans to install two to four characterization and monitoring wells in basalt formations in eastern and/or south-central Washington in 2023. If the data generated indicates those sites are appropriate for injecting supercritical CO_2 ($scCO_2$), Yale CCL will inject between 10,000 and 100,000 metric tons (MT) of CO_2 per well.

$scCO_2$ has been injected into basalt once before. Fewer than 1,000 MT CO_2 were injected, and post-injection monitoring lasted only two years. This initial test of the Columbia River Basalts provides evidence of great potential for permanent sequestration of large volumes of CO_2. However, many important technical questions remain unaddressed.

Further study is necessary before commercialization of this technology—this potentially globally significant CO_2 sequestration opportunity—takes place. Yale CCL's proposed pilot program will assess: (1) the process of CO_2 storage in basalt reservoirs, (2) the technique of injecting CO_2 in its supercritical form, and (3) the CRBG's storage capacity by studying:

(a) the migration behavior of larger volumes of $scCO_2$ in permeable basalt formations;
(b) stabilization of the injected $scCO_2$ plume upon termination of injection;
(c) rates and magnitudes of CO_2 mineralization in the post-injection period; and
(d) effects of pore water composition, basalt mineralogy, and other factors on the behavior of the CO_2.

Yale CCL will also research sampling and monitoring techniques to sufficiently track carbonate mineralization with isotopic tracers and other approaches to de-risk future, larger-scale injections. Yale CCL will publish its findings and will not be the operator of a Class VI well. For these reasons and more, Yale CCL believes its pilot wells qualify as experimental technology wells under 75 Fed. Reg. 77230, 77245–46 (Dec. 10, 2010) and *UIC Program Guidance #83: Using the Class V Experimental Technology Well Classification for Pilot Carbon GS Projects* (U.S. EPA, 2007).

Yale CCL knows the U.S. Environmental Protection Agency and Ecology share our concern about the changing climate and the unprecedented threat it poses. Given that there are two entirely defensible regulatory pathways, one of which moves a project that might address the impending crisis forward more quickly and another that will take years longer, we hope both agencies will choose the more expeditious yet equally safe pathway. All involved recognize that the operational, commercial sequestration wells will be required to obtain a Class VI UIC authorization. This request is not about avoiding that permitting process; it is about undertaking the research that supports it.

Members of my team and I will visit Seattle between September 14–16. With this admittedly short notice, we would be happy to schedule time with EPA and Ecology staff during our visit to answer questions and to discuss our submittal. If that timing is inconvenient for you, we would like to schedule a virtual meeting to discuss our submittal at your earliest convenience.

Sincerely,

Dean Takahashi

Dean Takahashi
Executive Director, Yale University Carbon Containment Lab

cc: Ryan Gross, UIC WA State Program Oversight, U.S. EPA
Daniel Feuer, Office of Ground Water and Drinking Water, U.S. EPA
Brook Beeler, Region Director, Eastern Region Office, WA Department of Ecology
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Dr. Anastasia O'Rourke, Managing Director, Yale University Carbon Containment Lab
Lauren Caplan, Associate General Counsel, Yale University Office of General Counsel
Jay J. Manning, Partner, Cascadia Law Group

1) Please describe generally the experimental goal(s) of this project. What will be 'tested' to further the science on carbon sequestration.

A. Project background

Climate change is an existential threat to our species and our societies, and Yale University's Carbon Containment Lab (Yale CCL) is driven to do its part to develop and implement solutions. Yale CCL is part of Yale University, a not-for-profit organization, with a mission to advance innovative, low-cost, safe, and verifiable methods of atmospheric carbon reduction, removal, and containment. It analyzes and scales both natural and technical solutions. Yale CCL's goal is not to deliver short-term profits; rather, it is to advance the science and market pathways necessary to stabilize the climate over the long-term. Yale CCL aspires to contribute to the containment of at least 50 million metric tons (MT) of carbon dioxide (CO_2) by 2035 and at the gigaton scale by the end of the century.

Yale CCL's efforts in Washington State include the "Carbon TrapRock Project," which will involve capturing CO_2 from several sources and permanently sequestering it in the basalt formation known as the Columbia River Basalt Group (CRBG). Professors at Yale University and the University of Calgary support the Carbon TrapRock Project, as do a host of contracted experts in geology, hydrogeology, carbon capture and storage, permitting and compliance, archeology and cultural resources, geographic information systems, economics, and volumetrics modeling. The Carbon TrapRock Project boasts several senior advisors with a long history of environmental and climate work in the Pacific Northwest region, in state economic development, geology and geochemistry, stakeholder engagement, and environmental justice. Technical and construction teams will be contracted when funding for the Pilot Project is secured.

Yale CCL team members include: Dean Takahashi, executive director and founder of the CC Lab, previously senior director of investments at the Yale Endowment, senior lecturer in economics and adjunct professor at the Yale School of Management; Dr. Anastasia O'Rourke, managing director, lecturer at the Yale School of the Environment, and a climate and sustainability expert with 20 years operational experience; Dr. Sinéad Crotty project manager; Dr. Abby Lunstrum, project manager; Jennifer Kasbohm, National Science Foundation Earth Sciences Postdoctoral Fellow at Yale; Alec Wallace, Charlie Mayhew, and Alex Wycoff, analysts; Ian Smith, business manager; and Daniella Rainero, project coordinator. Supporting Yale faculty advisors include: Professor David Bercovici and Assoc. Professor Noah Planavsky in the Department of Earth and Planetary Sciences, and Dr. Ingrid Burke, and Carl W. Knobloch, Jr., Dean of the Yale School of the Environment.

B. The CRBG formation

The CRBG is a regionally extensive set of thick basalt formations that cover over 200,000 square kilometers in the Pacific Northwest, primarily in Washington and Oregon. These basalt flows were deposited over several million years (Reidel et al., 2013). The CRBG has been proposed by numerous researchers as a significant storage resource for permanently sequestering CO_2, and initial characterization of the CRBG using surface exposures and existing subsurface data from groundwater and hydrocarbon exploration wells has led to estimates that its total storage capacity is as high as 10-100 gigaton (Gt) of CO_2 (McGrail et al., 2006; Blondes, 2019).

C. Prior research

In 2013, the Pacific Northwest National Laboratory (PNNL) and the Big Sky Carbon Sequestration Partnership, sponsored by the U.S. Department of Energy, injected 977 tons of supercritical CO_2 ($scCO_2$) at Wallula, Washington. Post-injection monitoring lasted two years. This pilot test indicated mineralization of injected $scCO_2$ occurs over short timescales (~2 years), which provides important preliminary evidence of the viability of long-term CO_2 storage in the CRBG (White et al., 2020).

Because the Wallula pilot injection provides the sole dataset about the behavior of injected $scCO_2$ in the CRBG basalt formations, additional data is required to accurately assess the viability and appropriateness of long-term CO_2 storage in the CRBG. CO_2 storage in basalts remains an unproven and experimental technology that, despite encouraging initial results, requires substantial additional scientific investigations to validate and potentially deploy as a solution for addressing atmospheric CO_2 reduction.

D. Experimental purpose

While results from the Wallula pilot were promising, there are several areas in which further research and experimentation are required before the CRBG can be used as a globally significant storage resource. Indeed, many questions need to be answered before a Class VI permit for commercialization of wells sequestering CO_2 basalts could be prepared and evaluated, and Yale CCL aims to answer them.

The Carbon TrapRock Pilot Project will build on the learnings of PNNL's preliminary research with further study and experimentation, including a pilot program expected to dramatically increase public and scientific understanding of this potentially large CO_2 storage resource. Yale CCL has conducted over a year of scoping and analysis regarding the potential for carbon sequestration in the region and has identified promising sub-regions based on geological sub-surface analysis. The next phase of investigation involves drilling two to four characterization and monitoring wells to better assess deep geologic formations in the CRBG and subsequently injecting 10,000 to 100,000 MT metric tons (MT) of $scCO_2$ per well into one to four pilot wells to determine the CRBG's potential for larger-scale sequestration (collectively, the "Pilot Project").[1] Yale CCL will test the injection and mineralization of $scCO_2$ in basalt and associated modelling, testing, and monitoring technologies to de-risk future sequestration efforts.

Present uncertainties that Yale CCL plans to study include the following:

- The migration behavior of larger volumes of $scCO_2$ (> 1000 ton) in permeable basalt

[1] Currently, the research team expects to inject $scCO_2$ into the basalts to study mineralization processes. In addition, the research will likely be of critical importance for exploring other potential injection approaches and strategies, such as the approach used by CarbFix in Iceland, or others.

formations;
- The stabilization of the injected $scCO_2$ plume upon termination of injection in basalt formations;
- Rates and magnitudes of CO_2 mineralization in basalt formations in the post-injection period; and
- Effects of pore water composition, basalt mineralogy, and other factors on the behavior of the CO_2.

This information is crucial for better assessments of the total CO_2 storage resource in the CRBG, for more accurate flow modeling for site characterization, and for area-of-review determination in future storage projects throughout the CRBG region. It is also crucial to ensure the protection of underground sources of drinking water (USDWs), as well as to protect from induced seismicity and durable storage; all important aspects of Class VI permits and a social license to operate.

i. Modeling

Nearly all existing data on CO_2 injection for long-term storage has been collected from sedimentary saline aquifer formations, depleted oil and gas reservoirs, and producing oil reservoirs associated with CO_2 enhanced oil recovery (EOR). Characterization and test injection projects and commercial carbon capture, utilization, and sequestration (CCUS) projects in sedimentary formations over the past two decades have provided a wealth of data about storage site characterization, CO_2 injection operations, CO_2 plume migration over time, and technologies and techniques for monitoring CO_2 behavior during and after injection in these formations.

The 2021 Global CCUS Status Report found that there are now 135 commercial carbon capture and sequestration (CCS) facilities worldwide in the project pipeline (27 are fully operational) from a diverse range of sectors including cement, steel, hydrogen, power generation and direct air capture. Notably, as of 2021, none of these projects involve basalt formations or mineralization. Rather, they are in sedimentary basins using enhanced oil recovery, saline aquifers, or depleted oil and gas fields (Global CCS Institute, 2021).

Critically, basalt formations in general, and the CRBG formations in particular, are substantially different than the sedimentary formations being used for the vast majority of CCUS projects. For example, the geologic characteristics of the flood basalts (e.g., mineralogy, depositional processes and history, porosity, and permeability structure) contrast significantly from those of sandstone saline aquifer formations, and the relative lack of data from the CRBG formations at depth prevent an accurate understanding of how CO_2 will behave in these basalt formations or the capacity of the basalt reservoir.

The current ability to numerically model $scCO_2$ flow and mineralization in basalt reservoirs is limited due to the dearth of subsurface data and laboratory analyses, as only a single injection test has occurred. Existing volumetric models such as StompCO_2 arguably do not adequately characterize mineralization effects and will need to be adapted to understand a potential area-of-review for site acquisition and/or permitting uses. Simply put, the kinetics of mineral formation—and the effects of this mineral formation on fluid flow—in a wide range of basalt projects are not understood well enough to reliably model basalt CO_2 injection in the CRBG. Additional formation and test data is needed to calibrate models for flow behavior, kinetics, rates of geochemical and mineralization reactions, and the types and volumes of the mineralization products and their effects on the storage reservoir (e.g., porosity reduction due to mineralization).

ii. Injection testing

If the characterization and monitoring wells provide positive results, the Carbon TrapRock Pilot Project expects to inject pure CO_2 in supercritical form. Under this approach, the CO_2 is not mixed with water prior to injection. This methodology differs from the methodology used by CarbFix in Iceland (as further explained below). As this technique has only been utilized once before (at Wallula), and at small volumes with limited post-injection research, it requires further testing and analysis for general use and acceptance.

The Wallula pilot injection provided important (but limited) data about the geologic and engineering characteristics of the CRBG formations. The pilot injection and subsequent modeling and lab analyses provided the first, and to date, the only data about the behavior of injected $scCO_2$ in these basalts. While promising, differing views on geochemical modeling about the efficiency and rate of carbon removal in basalt remain.

iii. Monitoring

Monitoring in basalts also poses new technical challenges, given the poor resolution of seismic data in basalts. Many newer technologies for monitoring, such as seismic imaging and fiber optic sensing, are untested in basalts. Nonetheless, the availability of new tools to track basalt carbonization (e.g., Pogge von Strandmann, et al., 2019) provides an additional impetus to further study CO_2 sequestration in the CRBG. Pilot Project injections will provide opportunities to test and compare several such newer technologies, which will inform a longer term understanding of the mineralization process and ultimate permanence of the sequestration. The goal of monitoring is to ensure that the CO_2 is safely contained, track mineralization rates, accurately measure durability, and ensure that drinking water resources are protected and operations are safe.

The focus of the Pilot Project is to address these uncertainties by collecting empirical data about the behavior of injected $scCO_2$ given the geological, geochemical, hydrological, mineralogical, and engineering characteristics of CRBG formations. This work will directly quantify the extent of CO_2 in an injection plume that is converted into carbon minerals (using Ca isotopes). These datasets will expand on the data from the Wallula project in three important ways: 1) collecting data associated with larger volumes of $scCO_2$ than was injected at the Wallula pilot, 2) testing the injection and mineralization of CO_2 at other locations within the CRBG, and in other basalt formations at different depths, than that utilized at Wallula, and by 3) providing a new opportunity to design sampling and monitoring techniques to sufficiently track carbonate mineralization with isotopic tracers and other approaches to de-risk future, larger-scale injections.

E. Conclusion

The Pilot Project should inform and support a scientifically based framework for operating and managing larger-scale geological sequestration projects in basalts. This project has the potential to meet the region's and the nation's climate ambitions, as stated in the 2015 Paris Agreement. In addition to decreasing emissions, the 2018 Intergovernmental Panel on Climate Change (IPCC) estimated that 5-10 Gt CO_2 must be removed from the atmosphere each year in the second half of this century to reduce the total load of greenhouse gases in the atmosphere to below the carbon budget for 1.5°C of global warming (IPCC, 2018). There remains a large gap between today's operational CCS locations and what is required to reduce global anthropogenic emissions to net zero (CCS Institute, 2021). Yale CCL is confident that the data collected and analyzed could help to evaluate whether and how the CRBG can live up to its potential for a large-scale, safe, and permanent carbon storage resource.

Additionally, please include information on these more specific questions regarding the project:

a. How do(es) the goal(s) of the project justify the need for multiple well sites?

An overarching goal for the Carbon TrapRock Project is to facilitate the safe and permanent reduction in atmospheric carbon through CO_2 storage in basalt formations throughout the CRBG. It is important to test and demonstrate whether this technology can indeed lead to a climate solution at the gigaton scale, sufficient to meet the needs of the climate crisis, and to match the scale of the CO_2 available in the region now and in the future. The primary avenue to accomplish this goal is to collect technical information and test methodologies that will improve the state of knowledge of carbon storage in basalts, increase the understanding of the characteristics of the CRBG that will affect injection of $scCO_2$, and decrease the uncertainties and risks associated with sequestering carbon in basalt.

The Pilot Project's use of multiple sites will enable Yale CCL to determine the feasibility and risks of carbon sequestration in the CRBG. Because of the variability of the basalt formations and their geologic characteristics across the CRBG, characterization and test injections at multiple sites and potentially at multiple depths are needed for a more refined understanding of the regional storage resource. Different volumes and sources of CO_2 and injection strategies may be deployed, as informed by the results of the initial characterization drilling and assessment. Importantly, assessing porosity, permeability, injectivity, and formation fluid pressures at multiple sites will allow for the variability of these parameters to be assessed and mapped across the basin. We anticipate that characterization and pilot injections at multiple sites will allow the Pilot Project to assess the viability of different formations, at different depths, and with different mineralogical and formation water characteristics to better define high potential areas for safe and permanent storage of significant volumes of CO_2.

Multiple sites also provide an opportunity to test different technologies and methods for managing injection operations, geophysical monitoring techniques during and after injection that are tailored specifically to basalts, and flow modeling with specific application to basalt storage reservoirs.

These datasets are fundamental to developing a framework for safely managing carbon storage projects in basalts and will allow industry and state and federal regulators to better understand the risks and opportunities for these projects to contribute to meaningful CO_2 sequestration.

b. *Why are the larger volumes of CO2 (compared to the Wallula project) necessary, specifically to the goals of this experiment?*

First, the Pilot Project is a critical interim research measure between the preliminary Wallula test and commercial-scale injections into basalt formations. While the results of the preliminary Wallula pilot injection are encouraging, they are insufficient to demonstrate the viability of the CRBG for CO_2 storage at a scale that could attract developers and investors to develop the CRBG as a critical component in solving the climate crisis. Commercial carbon storage projects typically utilize rates and volumes on the order of 500,000 to 1,000,000 t/year for multiple years.

PNNL injected 977 t of $scCO_2$, and the results and subsequent analyses demonstrated several important characteristics relevant to CO_2 storage in the CRBG basalts: that $scCO_2$ can be injected into permeable intervals within basalt formations, that the injected CO_2 remained within the intended injection zone and did not migrate vertically through the overlying low permeability caprock/seal formation, and that a substantial proportion (~60%) of the injected CO_2 mineralized within a short period of time (~2 years) (White et al., 2020). However, the modest volume of CO_2 injected during the Wallula pilot test was only sufficient to migrate a total distance of approximately 40 m from the well into the injection zone. The Wallula injection test utilized very low injection rates of approximately 40 t/day (25 days total injection time) to manage the formation fluid pressure (McGrail et al., 2014). In addition, post-injection monitoring was limited due to the rapid stabilization of the modest volume of CO_2 injected, the rapid mineralization of a large proportion of the injected CO_2, and timeframe and budget.

Yale CCL is considering CO_2 volumes smaller than commercial volumes but substantially larger than used at Wallula. Yale CCL proposes to inject 10,000 to 100,000 t (total injected volumes) $scCO_2$ per well. These larger volumes would allow the CO_2 plume to develop fully, migrate further from the injection wells, and be monitored in more detail during and after injection. Larger CO_2 injection volumes also provide the opportunity for post-injection sampling of mineralized CO_2 at different locations within the plume through later drilling and core sampling, which is needed to accurately quantify integrated carbonate precipitation rates. These results would provide significant improvements in scientific knowledge of how CO_2 migrates within and interacts with basalt formations. With commercial injection wells costing as much as $20M to complete, the Pilot Project aims to demonstrate that the CRBG's storage capacity could potentially sequester commercial volumes of CO_2 such that future researchers and operators will invest in its potential to help solve the climate crisis.

Second, the Pilot Project will enable the collection of sufficient data to inform a scientifically sound management framework for sequestering CO_2 in basalts using mineralization. The existing Class VI requirements and guidance were written largely in the framework of regulating storage in sedimentary formations, and the techniques used to model, image, and monitor plumes of injected CO_2 have been developed for these types of lithologies. CO_2 storage in the CRBG likely will require different characterization and monitoring techniques than typically used in sedimentary saline aquifers. For example, seismic data may be less effective for defining reservoir levels due to the physical properties of basalt formations, and 4D seismic imaging is unlikely to provide high-quality images of injected CO_2 as in sedimentary aquifer storage projects. Relatedly, Class VI requirements, such as being able to clearly predict an area-of-review, cannot be completed for basalt reservoirs with available reactive transport volumetric models, as they do not calculate mineralization effects or reaction kinetics. The data obtained from the Pilot Project will be key to developing modeling and monitoring methodologies for CO_2 in basalt reservoirs that will be necessary for future projects to comply with Class VI rules.

c. ***What are the criteria for deciding the final volume of CO_2 necessary to complete the project goals?***

The final volumes of $scCO_2$ to be injected will be proposed to the appropriate regulatory agency in a Pilot Study Plan based on the results of the characterization wells and on the key technical risks requiring testing. The CO_2 volumes necessary to characterize the injectivity and storage volumes of the CRBG formations will vary based on the geologic and hydrologic characteristics of each site. Other criteria for injection volume include feasibility concerns, such as the availability, access, and cost to buy and safely transport $scCO_2$ to the site.

If deemed appropriate by the responsible agency based on the characterization data, the final injection volume will be at least 10,000 tons per well but will not exceed 500,000 tons in the aggregate across all wells. Yale CCL will limit the volume of $scCO_2$ injected per site and in the aggregate consistent with state and federal regulatory restrictions.

2) ***How does achieving the experimental goal(s), above, expand our understanding of basalt mineralization beyond what is known from the CarbFix program in Iceland or the Wallula project in the CRBG in Washington State?***

First, the CarbFix program in Iceland uses a fundamentally different process than is being considered for the Pilot Project. CarbFix uses a process in which CO_2 and hydrogen sulfide (H_2S) are dissolved in water, which is then injected into basalt formations at temperatures of up to 260 °C (Clark et al., 2020). The CarbFix injection tests have shown that up to 95% of the dissolved CO_2 mineralizes into calcite within two years (Clark et al., 2020). The water requirements of the CarbFix approach are significant–it is estimated that approximately 25 tons of water is required for each ton of CO_2 sequestered using this method (GCCSI 2021). Some researchers also remain concerned about the risk of formation plugging from the development of highly localized precipitation shock fronts (McGrail et al., 2014).

In contrast, Yale CCL intends for the Pilot Project to utilize a similar design to the Wallula pilot, though larger volumes of CO_2 and using and testing different monitoring approaches. The tests will inject pure CO_2 in supercritical form; the CO_2 will not be mixed with water prior to injection.

This difference is important, especially considering the West Coast's drought conditions, as the injection of $scCO_2$ does not require the large volumes of water that are needed for the methodology used by CarbFix. Because of this difference, however, the results of the CarbFix injections are not directly applicable to CO_2 storage in the CRBG, and additional pilot injections are necessary to further study the science and technology. That said, many of the monitoring tools developed to track carbon fluxes in the CarbFix project should be applicable at the CRBG.

Second, the test injections proposed for the Pilot Project are necessary to provide data beyond the information gained from general regional characterization efforts and the preliminary Wallula pilot injection, which used a nominal injection volume of 977 tons and very low (sub-commercial) injection rates and performed only one set of post-mineralization sampling. Larger volumes and higher flow rates at multiple sites are necessary to obtain additional data to understand the storage resource of the CRBG and basalt sites worldwide.

Better understanding the technology of injecting $scCO_2$ into basalts for mineralization will promote the protection of underground sources of drinking water, address concerns of induced seismicity stemming from CCS projects, and ensure that CO_2 is permanently stored without risk of leakage.

3) Will Yale CCL commercialize this project at the end of the research phase, or participate in the commercialization process?

Yale CCL's mission is to investigate opportunities and techniques for removing and sequestering atmospheric carbon at a scale necessary to combat the climate crisis. Yale CCL aims to de-risk carbon removal and sequestration projects and to mobilize the resources necessary to unlock implementation pathways. Yale CCL views its role in performing characterization and assessment activities at multiple sites in the CRBG (the Pilot Project) as key to facilitating the carbon storage industry in the Pacific Northwest region to hopefully help "open up" this resource and solution.

As such, the Pilot Project will be designed to research and increase knowledge about the subsurface characteristics of the CRBG formations; the behavior of injected CO_2, including flow and mineralization; effective monitoring and verification methods; and the large-scale storage resource volumes of the CRBG. Yale CCL plans to publish results of its tests and analyses in academic and industry journals to facilitate the transfer of lessons learned to the greater CCUS community.

For the avoidance of doubt, Yale CCL will not serve in the role of a commercial project developer. Yale CCL will not profit from the Pilot Project, and it will not subsequently apply for a Class VI Underground Injection Control (UIC) permit to commercially operate wells geologically sequestering CO_2 in the CRBG. However, Yale CCL expects and hopes that the data gleaned from the Pilot Project will be used to support future applications for Class VI UIC permits by others.

It is entirely possible that Yale staff members or the University itself will have an interest, financial, research, or otherwise, in a subsequent commercial proposal. Yale CCL will not prohibit its faculty, staff, or research partners (*supra* at question 1) from forming a private organization or assisting an existing one in pursuing commercial sequestration opportunities in the CRBG should the Pilot Project prove successful.

4) *Would Yale CCL or other project proponents accept payment or other forms of compensation from CO2 generators, partners, or other stakeholders that would directly benefit from this project?*

No. Yale CCL is funded directly through gifts made to advance its broad mission of enabling carbon containment at the gigaton scale by the end of the century. It does not receive funding or compensation from commercial operators or partners to develop CO_2 storage projects. Yale CCL is advancing the Pilot Project as part of its mission of facilitating meaningful and permanent reductions and removal of atmospheric CO_2.

Yale CCL is currently investigating potential partners to provide CO_2 for the pilot injection projects, but, to date, no commercial agreements have been made with respect to CO_2 off-takers/suppliers. Yale CCL is also working to identify site locations appropriate for injection, which could involve lease agreements with private landowners and/or the Washington Department of Natural Resources. Both the CO_2 off-takers/suppliers and the landowners may later associate themselves with entities commercializing carbon sequestration in the CRBG, should Yale CCL's Pilot Project prove successful.

The Pilot Project will cost approximately $15 million to $20 million per site. Yale CCL and/or its partners anticipate applying for funding supporting the Pilot Project, such as from the U.S. Department of Energy, State of Washington, and/or philanthropic sources. Funding from private sources may also be needed to advance this research, though none is being considered at this time.

5) *Please discuss how the data generated by this project will be used. Will the data be shared with the scientific, industrial, or regulatory communities? Will the data be sold or given to exclusive commercial partners?*

The Pilot Project is a Yale CCL-led research project aimed at (1) understanding the process of CO_2 storage in basalt reservoirs, particularly the behavior of CO_2 during and after mineralization—including for longer than two years post-injection, (2) testing the technique of injecting CO_2 in its supercritical form, (3) determining the CRBG's CO_2 storage resources and capacity for larger-scale sequestration, and (4) confirming safe and effective monitoring and verification approaches for carbon sequestration in basalt. The data collected through the characterization and monitoring wells, pilot injection tests, and subsequent monitoring at the Pilot Project sites will be used to better understand the behavior of CO_2 in the basalt formations of the CRBG, with a focus on plume migration, mineralization, and long-term CO_2 storage security.

Yale CCL intends that data collected and analyses performed during the Pilot Project will be made publicly available such that future research and commercial basalt-sequestration projects may be realized. Yale CCL works directly with multiple Yale faculty members (e.g., those in the Department of Earth and Planetary Sciences), as well as faculty from other universities, who will be involved in this research with the end goal of producing open access, peer-reviewed scientific literature.

Further, it is Yale CCL's intention that data and analyses from the Pilot Project will not be sold or given exclusively to commercial partners. What we do not know now is whether subsequent contractual relationships might limit data availability or require that certain data be kept confidential or sold or shared with certain commercial partners. For example, owners of the land where the pilot wells are located might insist that certain data be kept confidential, or an operations partner might insist that certain data be shared with them exclusively. Yale CCL will try to avoid such contractual limitations but cannot guarantee that we will be successful in that regard.

The CRBG has the potential to anchor a major carbon storage hub in the Pacific Northwest. Data gathered through the Pilot Project and shared with the scientific community will help advance and de-risk projects using basalts for geologic sequestration in the U.S. and abroad. The Pilot Project will prove out the technology, reduce operational and technical risks, and ensure the protection of public health. If the Pilot Project is successful in meeting these goals, it will also give all stakeholders the confidence to support carbon sequestration at a scale meaningful to address the climate crisis.

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